THE RADAR WAR

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Forward

The backbone of any military operation is the Army. However for an international war, a Navy is essential for the security of the sea and for the resupply of land operations. Both services can only be successful if the Air Force has control over the skies in the areas in which they operate.

In the WWI the Air Force had a minor role. Telecommunications was developed during this time and in a few cases it played a decisive role.

In WWII radar was able to find and locate the enemy and navigation systems existed that allowed aircraft to operate over friendly and enemy territory without visual aids over long range. This development took place at a breath taking speed from the Ultra High Frequency, UHF to the centimeter wave length. The decisive advantage and superiority for the Air Force or the Navy depended on who had the better radar and UHF technology.

0.0 Aviation Radio and Radar Technology Before World War II

From the very beginning radar technology was of great importance for aviation. In spite of this fact, the radar equipment of airplanes before World War II was rather modest compared with the progress achieved during the war.

1.0 Long-Wave to Short-Wave Radiotelegraphy

In the beginning, when communication took place only via telegraphy, long- and short-wave transmitting and receiving radios were used.

2.0 VHF Radiotelephony

Later VHF radios were added, which made communication without trained radio operators possible.

3.0 On-Board Direction Finding

A loop antenna served as a navigational aid for airplanes. This system combined with the on-board receiver made it possible to take a rudimentary bearing on radio stations and later on UHF direction beacons. Later a special receiver was developed that together with an auxiliary antenna enabled lateral location finding. In Germany another direction-finding receiver was developed that at the same time could pulse switch the phase of the auxiliary antenna and the output voltage so that an unambiguous bearing accuracy similar to the minimum bearing could be achieved without switching to minimum input voltage. The loop antenna, with its high aerodynamic drag, was replaced by a strip antenna placed in a flat covered housing.

4.0 Ground Based Direction Finding

If the airplane had no direction-finding equipment on board, a ground-based fix could be requested via radio. Two or more well spaced ground stations would locate an aircraft or ship to create radio navigation position lines which had a hyperbola shape.

5.0 Pip-Squeak. English Direction-Finding Procedure VHF

English fighter planes equipped with a radiotelephone (λ=2-3m) use the Pip-Squeak procedure for their bearings.[2 pg 17] The procedure consists of switching the board transmitter after 45 seconds to a sound-modulated direction-finding frequency (λ=7m) for 15 seconds.[1 pg 89] A time switch on the instrument panel indicates the time reserved for direction finding that cannot be used for talking by a red section on a disk.

6.0 Instrument Landing System (ILS) VHF

Deutsche Versuchsanstalt für Luftfahrt (DVL), translated "German Aeronautic Research Institute," developed a procedure built by the Lorenz Company for landing in bad weather. A pulsed AN signal of a VHF transmitter is received during approach and is switched in such a way that an A or N signal indicated a deviation from the selected approach path. This signal turned into a continuous hum when the airplane was on the approach path. A needle moving either to the right or left of an instrument served as visual indicator. VHF beacons transmitted in the direction of the approach and vertical beams pointing upward marked the distance to the point of touch down.

7.0 Hyperbola Procedure

All points for the difference in distance from two fixed points is constant, lie on a hyperbola. Several navigation aids were developed by applying this principle of measuring the time difference of the cylces.

7.1 DVL Hyperbola Procedure VHF

Suggested by Prof. v. Handel, German Aeronautic Research Institute, DVL**,** started the development of a procedure in which two transmitters are separated by a distance of a few 100 wavelengths.[5] The transmitters are controlled by a common VHF oscillator were a rotating Goniometer changes the frequency of one transmitter by a few Hertz. In this way hyperbolic interference lines are produced that traveled from one transmitter to the other and are rotated at a great distance. By computing the maximum values at one particular point, one determined the direction toward the transmitters. This research project had to be stopped in 1939.

7.2 Ingolstadt. German Navigation Procedure l =100-200m

In the hyperbola procedure developed by the Telefunken Company, two transmitters positioned at great distance from each other emitted pulsed beams that are synchronized to the ground wave.[2 pg 75] Each time difference in recorded cycles corresponded to a hyperbolic stationary line. This research project also had to be discontinued in 1939.

8.0 "Elektra" or "Sonne," German VHF Navigation Procedure

A radar beacon emits an unmodulated VHF wave from a kidney-shaped antenna rotating around its vertical axis.[2 pg 136] The resulting field strength is then received at fixed points as a sine-shaped modulated wave. In order to be able to measure the spot within phase that indicates the azimuth of the receiving point, the radar beacon emits an additional reference signal synchronized with the rotation frequency at the antenna. The phase difference measured on board the aircraft or ship indicates the direction of the radar beacon.

9.0 Development of Radar Technology in Germany

<u>4 April 1904</u>

As early as 1904 the German engineer Hülsmeyer in Duesseldorf received a patent (US patent 810,150 dated 1906) for a procedure that showed reflections from a ship at a distance of 1,000 m (later 3,000m).[2 pg 34,285]

<u>1916</u>

In 1916 Hans Dominik, an engineer at Siemens, tries to pinpoint enemy targets in the same way with a spark discharger type transmitter.[2 pg 2] But the time for this technology had not yet come. It was only in the 1930s during the development of the VHF technology that more and more often disturbances were observed that were caused by the interference between a direct wave and one reflected from an obstacle. Engineers from almost all industrialized nations undertook experiments to utilize this effect and pinpoint targets with the help of reflected waves. Since these experiments had military applications, they were usually kept secret and not publicized until after World War II. When Dr. Kühnhold, scientific director of the Communications Research Institute of the German Navy, [2 pg 39] was working on underwater acoustic bearing (sonar), he tried to find a procedure that would utilize radio wave reflections for locating ships. When he received a recommendation from *Dr. H. E. Hollmann* referring him to use a 50cm, 40W magnetron from the Dutch company Philips, [3 pg 9] he ordered two tubes and had a test unit built.

<u>January 1934</u>

Since Telefunken is not interested in the project - Dr. Runge rejects an invitation to cooperate with Dr. Kühnhold because he thinks it is a utopian idea - a new company, GEMA, is founded for the purpose of developing radar.[1 pg 39]

<u>20 March 1934</u>

At the first trial, a 50cm transmitter, modulated by 1,000 Hz, with a Yagi antenna and a receiver equipped with the same type of antenna is used. Reflections from a ship can be ascertained, but only at a distance of 20m. In the next test with a 13.5cm Pintsch transmitter of 0.3W, reflections from a distance of 100m are received.

<u>24 October 1934</u>

Using a 50cm transmitter erected at the height of 10m and a receiver, also erected higher, a range of 120km is achieved with the test boat "Grille" at a distance of 200m.[1 pg 41] At this test, echoes from an airplane are accidentally received. As a consequence, the following research goals are established: Transition from the continuous wave system to impulse transmission in order to

increase performance and to be able to lock the receiver during transmitting impulses so that the same antenna can be used for transmitting and receiving. The cycle time of the impulse can now be made visible with a cathode ray tube and, as a result, the distance can be measured.

9.1 “Seetakt” (DeTe). German Ship Radar l =80cm

Based on the aforementioned principles, GEMA Company builds a device with a wave length of λ=50cm. Using a mattress antenna with duplexing characteristics, the device attains a bearing accuracy of ±1 degree.[2 pg 5]

26 September 1935

This device is shown to Admiral Raeder. In a test with the high-speed gun ship “Bremse” a range of 8km and a bearing accuracy of ± 2 degrees are attained.[1 pg 50]

Based on this device, the “Seetakt”_is developed with a wave length λ=80cm and an azimuth resolution of 30 degrees that attains a range of 14km for detecting ships.

9.2 “Freya.” German Ground Radar l =2.40m

Since there are no efficient tubes available for shorter wave lengths, GEMA develops a ground radar with a wave length λ=2.40m that has a separate antennas for transmitting and for receiving.

End of 1936

A prototype radar that locates airplanes at a distance of 80km is shown to Martini, who at that time is an Air Force colonel. Martini places an order for 12 “Freya” radars.

Fall of 1937

Three “Freya” and one “Seetakt” radars are employed at the fall military maneuvers in Swinemünde.[1 pg 54]

9.3 “Stichling.” Identification Friend or Foe (IFF) for “Freya” l=2.40m

Fall of 1937

GEMA proposes a plan for a radar that makes it possible for the “Freya” radar to identify friendly planes. Martini puts in an order for 3,000 devices, the Air Force Ministry of the Reich, however, has 10,000 devices of the FuG 25 “Zwilling” built which prove to be worthless.[1 pg 129]

9.4 “Würzburg.” German Ground Radar l =54cm

Spring of 1935

Dr. Runge from Telefunken, who has initially viewed the radar idea with skepticism, a year later starts an experiment in Groß Ziethen that, employing a magnetron λ=50cm, 5W, achieves strong reflections from a Ju 52 aircraft flying at an altitude of 5,000m.[1 pg 45] The management of Telefunken, however, shows no particular interest in this project. In spite of management’s resistance, the “Darmstadt” radar, utilizing pulsed doppler is developed in 1936. It can locate distance, azimuth, and height of airplanes at a distance of 5km with an accuracy of 50m. But General Udet and the anti-aircraft officials show no interest.

Fall of 1938[1 pg 56]

It is not until the fall of 1938 that the German Air Force authorizes the development of this radar.

<u>Beginning of 1939</u>

At this time Telefunken, at the urgent request of Dr. Kühnhold, develops a 50cm magnetron with an peak power of 10 kW within a few weeks. With the magnetron the radars range is increased to 40km.

<u>July 1939</u>

The first "Würzburg" radar is shown to Hitler in Rechlin.[1 pg 56] This radar is an improved "Darmstadt" radar. It has a wave length of λ=54cm, a peak power of 8kW, and a 3m parabolic antenna dish with rotating dipole. Its range for airplanes is 30km. This radar is mounted on a gun mount and can be operated by one person. An order is not placed until three months later, but then for 5,000 units. Altogether 4,000 Würzburg radar sets were delivered during the war.[1 pg 287]

9.5 "Erstling" IFF for "Würzburg"

<u>1939</u>

In order to identify friendly airplanes, Telefunken develops an IFF system for the "Würzburg", the system is ready for production in 1939. General Martini wants to place an order, but is prevented from doing so by the Air Force Ministry of the Reich. [1 pg 15]

10.0 Development of Radar Technology in England

<u>1934</u>

The Tizard Committee for the Scientific Study of Air Defense is founded.

<u>12 February 1935</u>

Watson Watt proposes a plan for an installation that utilizes waves reflected from enemy airplanes for locating them.

<u>September 1935</u>

At a test installation, λ=26m reflections from airplanes at a distance of 100km are observed.

10.1 Chain Home (CH). English Coast Radar Installation l =12m

<u>December 1935</u>

It is decided that the coast radar installation Chain Home (CH) with five stations be constructed. Each station has four transmitter tower antennas and four offset receiving tower antennas, each 80m high. The distance is calculated from the pulse cycle time, the azimuth angles from the phase difference between the antennas positioned parallel and at a 90 degree angle to the reflected signal are measured by a Goniometer. To make sure that the various stations do not interfere with each other, the stations are located a distance apart. Later, pulses are first sent at a frequency of 50Hz, then of 25Hz, and are synchronized by pulse modulation. [1 pg 80]

<u>End of 1937</u>

Five stations at the southeast coast are ready for action.

<u>1938</u>

It is decided that CH will be increased to 18 stations. There is a plan to add 1.50m devices to track low-flying aircraft. [1 pg 286]

<u>Spring of 1939</u>

The CH is finally up and running, with 19 stations in operation by September.

The German command force has no knowledge of the existence of CH, the obvious antenna installations are taken to be marine radio stations. General Martini, however, is afraid that the English might have radar type devices and gets approval to deploy a Zeppelin for a reconnaissance flight.

August 1939

Two reconnaissance flights brought no indications of any English radar activity since the Germans were looking for higher frequencies that what the radio frequencies the CH was using.

10.2 Type 79Y. English Ship Radar l =6.40m

October 1935

The English Navy starts to develop radar for ships.

Spring of 1938

The ship "HMS Saltburn" is equipped with a radar, λ=6.40m, an output power of 15kW, [2 pg 17] and antennas consisting of a double array with a reflector that rotates at the top of a mast. The test is successful, and two radars of Type 79Y are built and put in operation.

August 1939

An improved version, Type 79Z, with an output power of 70kW is put in operation and can track airplanes up to a range of 100km.

10.3 ASV (Anti Surface Vessels). English Airplane Radar l =1.50m

1935

The English Air Force orders the building of a radar to locate ships.

4 September 1937

First flight with an ASV prototype. In spite of very bad weather conditions, the searched [1 pg 73] for a naval formation is found and a series of fighter planes taking off from an aircraft carrier is even identified.

Fall 1939

The production of ASV radars for airplanes begins. The first units are put in operation in airplanes of the Coast Command.[1 pg 79]

Radar Development During the Second World War

L39.0 Air War 1939

Poland

Since the Poles had been guaranteed protection by England, they believe that they can pursue the Polish nationalization of those German areas promised to them after World War I in such a way that the complete destruction of anything German was to be achieved in a short time.

30 September 1939

The campaign against Poland put an end to this endeavor.

England

3 September 1939

England declares war against Germany.

France

France follows England's course of action only after massive pressure from Churchill.

Germany

At the outbreak of the war, in addition to the blackout of cities, all German radio stations are switched to the same frequency to prevent enemy airplanes from orienting themselves with the help of these radio stations. Signs at railroad stations that could be read easily during the day are removed.

L39.1 Chain Home (CH). English Coast Radar Station λ =12m

September 1939

England's CH is ready and put in operation in September 1939. Nineteen stations survey the air space beyond the English south and east coast.

L.39.2 "Pip Squeak." English Direction Locating λ =7m

September 1939

English fighter planes located by CH are identified by "Pip Squeak" direction locating and directed toward enemy targets.

The German generals don't want to believe that fighter planes could be directed from ground stations. It takes the results of radar surveillance and a captured "Pip Squeak" device to convince them of the fact.

L39.3 Freya. German Ground Radar for Air Surveillance λ =2.40m

September 1939

Seven Freya radars are ready for air surveillance at the beginning of the war. They are movable ground systems with a array mattress antenna that can measure direction and distance to the targets with an azimuth resolution of a good 30°. All in all, 2,000 units are delivered during the war.

October 1939

The first experimental Freya radar is placed on Wangerooge.

18 December 1939

Freya locates a series of airplanes at a distance of 113km and directs fighter planes towards them: 15 planes are downed.

L39.4 German Analysis Agency for Captured Airborne Radio and Radar

October 1939

The German Aeronautic Research Institute (DVL) presents a report about a radar unit captured from a Polish airplane to the Air Force Ministry of the Reich (RLM).[5] The RLM sends all captured radar devices to the DVL. The DVL maintains the responsibility for the analysis of all

captured radar systems except for installations in the cm range until the end of the war. (Investigator for the DVL is G. Hepcke)

L40.0 Air War 1940

English Air Attacks

Since losses during day time attacks are too high, the English fly attacks only at night and bomb targets along the Rhine.

L40.1 Würzburg. German Flak Guiding Radar l =54cm

The Würzburg radar is ready for operation by the flak.

<u>May 1940</u>

At its first deployment in Essen, with the measurements transmitted orally to the flak, a plane is downed. No visual contact is used.

<u>October 1940</u>

Beginning in October, the radar is used in quantity by the flak. Soon after that all flak gun laying is automated.

L40.2 AI (Air Interception). English Night Fighter Radar l =1.40m

After successful tests in November 1939, night fighter aircraft are systematically equipped with on-board radar.

French Campaign

<u>10 May 1940</u>

German troops enter Holland.

<u>27 May to 3 June 1940</u>

Suffering heavy losses, the English leave France at Dunkirk. Among the German booty a transportable 4m radar is discovered.

<u>22 June 1940</u>

Truce in Compiegne.

L40.3.1 Chain Home (CH). English Coast Radar l =12m

The Germans observe 12m pulse signals at the western front without being able to recognize their origin and purpose.

<u>June 1940</u>

In the middle of June the German Aeronautic Research Institute (DVL) is given the task of explaining the nature of these signals. A special group under the direction of Professor von Handel finds out that the signals originate from radar installations and from the coast of the English Channel. They pinpoint the location of the 12m CH installations that up to then had been thought to be coastal radio stations. The scientists observe that the transmissions of the individual stations are pulse modulated to avoid mutual interference. In addition more radar installations in the 6m and 3m range are discovered and located. After two short weeks a map of the complete system of CH installations in the south of England is delivered to the Air Force Ministry of the Reich (RLM) that had so far been completely unaware of their existence. Air Force captains are informed that clouds provide no protection from being discovered prematurely, only flying low does.

L40.3.2 German Aviation Research Institute's Jamming Station l =12m

The fact that the CH stations are connected with each other through pulse modulation raises the possibility that interfering with one station would disturb the whole system. Therefore the German Aeronautic Research Institute (DVL) immediately builds a jamming station with sound barrage jamming.[5]

July 1940

Its deployment at the beginning of July 1940 at the coast of the English Channel is successful and puts the CH out of operation for some time.

L40.3.3 Radar Checkpoint

July 1940

Radar checkpoints that also operate the jamming stations are installed at the coast of the English Channel. Later these jamming stations are consolidated into one station in Calais.

L40.3.4 Second German Aviation Research Institute's Jamming Station l =12m

Because it was obvious that the English would soon employ counter measures to the simple sound barrage jamming**,** the German Aeronautic Research Institute (DVL) builds a second jamming station that according to the Ball principle responds to each received impulse with an interfering impulse.[5]

September 1940

The second jamming station operating at Cape Griznez is successful for a limited time.

L40.3.5 The Concept for Garmisch-Partenkirchen l =4-12m

July 1940

In order to increase the degree of interference, Dr. Owczarek suggests to send back several groups[5] of staggered pulse beams instead of one synchronized pulsed beam in order to simulate a series of planes. An order for five jamming stations with the cover name "Garmisch-Partenkirchen" is placed with the Hagenuk Company. They are deployed during operation "Donnerkeil" (Thunder Wedge).[1 pg 133]

L40.3.6 Target Flight against the CH Stations

To effect a flight against the CH stations directly, the German Aeronautic Research Institute (DVL) equips an He110 aircraft with target homing device developed for this particular application.[5]

12 August 1940

Except for a test flight on the English coast, the aircraft is not used in this capacity. It is proven that the installations protected by balloon barrages cannot be completely demolished by either long-distance guns or bombing.[5]

L40.3.7 Further German Aeronautic Research Institute's Jamming Station l =10-15m

The German Aeronautic Research Institute (DVL) changes 1kW Army stations into jamming stations, first with alternating modulated frequency, then with pulse modulation.[2 pg 112]

L40.3.8 "Breslau I," Type S604/2. German Jamming Station l =6.0-7.5m

To interfere with the English coast radar stations, the installation consists of five separate stations of 1kW whose frequency is modulated at plus/minus 0.7kHz by a rotary condenser so that the whole range of 22-28MHz is being interfered with. The modulation is achieved with synchronized and unsynchronized pulse sequences. The synchronization during a short transmission of the pulse recurrence frequency is continuously supervised.

L40.3.9 "Breslau II," Type S604/2. German Jamming Station l =6.0-7.5m

The station "Breslau II" operates on the same principle as "Breslau I" but on a shorter wave length.

L40.3.10 R 3000 (Identification Friend or Foe). English IFF l =12m

<u>April 1940</u>

Among the radar devices delivered to the German Aeronautic Research Institute (DVL) there are some that seem to be simple feedback receivers that are mechanically modulated at a 12m wave length. At first their purpose is unclear because switching at the decisive wave length is regularly dispersed with the help of an accelerator switch. At the German Aeronautic Research Institute, a tiny piece of wire gives rise to the conjecture that it is part of a connection between the end and feedback stages. Then the received and amplified impulses from the CH increase the feedback stage so that it sends back an identification impulse on the CH wave. Because the Air Force Ministry of the Reich (RLM) does not accept this explanation, the German Aeronautic Research Institute (DVL) switches an R3000 device to the "Freya" frequency. The subsequent test removes all doubts and furthermore shows that the device increases the range of the "Freya" to a good 150km. Later units are captured that cover all other wave length ranges of the English coast radar.

L40.4 Chain Home Low (CHL). English Coast Radar l =1.50m

The English 12m coast radar installations have a large range but have difficulty picking up single airplanes and low-flying planes. They are also difficult to operate because of their Goniometer technique.

<u>Beginning of 1940</u>

At the beginning of 1940, 1.50m radars with a movable antenna are added to the CHL.

<u>End of 1940</u>

At the end of 1940 these radars are improved by adding a rotating antenna (360 degree azimuth) and altitude, elevation recording methods which the CH did not have.

L40.5 Masking Beacons ("Meacon"). English Long Wave Jamming Stations

<u>Summer 1940</u>

In order to make it impossible for German airplanes to use the long wave radio communication, starting in summer 1940, the English use "Meacon" jamming stations keyed synchronously to the transmitting radio stations. [2 pg 135]

Air War in England

<u>August 1940</u>

After the English broadened their night air attacks to include cities outside the Rhein region, such as Munich, Hanover, and Berlin, the German Air Force intensifies day air attacks at English Air Force bases and other strategically important targets as preparation for the planned invasion "Seelöwe" ("Sea Lion"). They cause severe damage but fall short of their goal of defeating the Royal Air Force. [1 pg 84]

<u>15 September 1940</u>

On 15 September 1940 an extensive attack on London takes place. When the English defense is failing, the attack is stopped. Thanks to their disciplined execution, the English utilize their defense so effectively that the German losses become too high (25 percent). The goal of attaining superiority over the Royal Air Force is not reached. Now the Germans switch to night attacks with the help of radio navigational aids. [1 pg 95]

L40.5.1 "Knickebein" ("Knock-Knee"). German Navigational Procedure l =10m

At first the German air attacks use the "Knickebein" procedure in which a UHF beam is used for navigation. The instrument landing system technology that had been developed by the Lorenz Company before the war is used. The intersection of a beam with a second beam pinpoints the target. [4 pg 25]

<u>November 1940</u>

During the night of 15 November 1940 the industrial targets at Coventry are attacked. [1 pg 180]

L40.6.2 English Interference Measures

The English use jamming stations that make it impossible to recognize the correct signals by keying in wrong ones.

L40.7.1 German X Procedure l =4.30m

<u>End of 1940</u>

The X procedure uses the same principle as the "Knickebein" procedure, only on a shorter wave length. At the intersection point of the navigation position lines, the bombs are released automatically.

L40.7.2 English Jamming Measures

At first the procedure is immune to interference because the English have no suitable transmitter.

L40.8.1 German Ultrashort Wave Y Navigational Procedure

The Y procedure, introduced at the end of 1940/beginning of 1941, provides both the indication of direction and distance. In order to achieve this, the sound modulation of the ground transmitter received by the airplane is sent back with a different frequency. The distance calculated from the phase difference is sent out by means of synchronized pulses.

L49.8.2 English Jamming Measures

The English jamming measures are immediately successful because the procedure had been disclosed by espionage. It is, however, used later to complement the "Himmelbett" procedure (L41.3).

L40.9.1 Freya. German Ground Radar l =2.40m (9.2) with a Short Wave Transmitter Added

To be able to use the "Freya" device to guide fighter planes and to identify their own fighter aircraft, Lieutenant Diehl adds a short wave transmitter to his radar.

<u>5 May 1940</u>

On 5 May he succeeds in guiding German fighter aircraft to English bombers 50km away above the North Sea so that two bombers are shot down.

L40.9.2 Illuminated Night Chase with "Freya" Parasite

Spotlights guided by a "Freya" radar can now spot enemy airplanes even in overcast skies so that the night fighter aircraft can locate the enemy airplanes.

<u>16 October 1940</u>

First successful downing of an airplane.

L40.9.3 Dark Night Chase with "Postkutsche" ("Stage Coach") Procedure

The "Freya" radar that is now equipped with an AN-pulsed signal instead of the simple azimuth apparatus to identify friendly aircraft is used as "Postkutsche" procedure for guiding fighter planes. The course to enemy aircraft is transmitted by voice communication.

<u>16 October 1940</u>

First downing by the "Postkutsche" procedure.

L40.9.4 English Jamming Measures

The English key in wrong data.

English Downing Results

<u>End of 1940</u>

English air reconnaissance finds out that the downing results for night attacks are so bad that they don't justify the high losses of airplanes. The number of attacks are reduced.

Tizard Mission

Since the English are convinced that they cannot win the war without help from other countries, they pull the United States of America into the war. [3 pg 23]

<u>September 1940</u>

At the beginning of September the Tizard mission transfers all secret English military developments to the Americans. Among the radar devices there is a search device for ships, ASV Mark II, and a night fighter aircraft radar AI Mark IV. The Americans immediately install the devices in their own airplanes and test them. By far most important piece is the multi cavity magnetron, invented in Germany (see Hollmann's US patent 2,123,728) and improved upon by the French and English to a pulse peak power of 50kW at a wave length of 9cm. During the course of the war the Americans produce more than a million cavity magnetrons. [1 pg 287]

L40.10 "Caruso." German Jamming Station l =2.50-3.00m

In order to prevent English fighter planes from being guided by voice communication from the ground, the German Central Post Office develops the jamming station "Caruso" with a performance of 30kW. [2 pg 170]

The full production of this installation, consisting of two transmitters modulated by delta pulses for the ranges λ=2.50–2.70m and λ=2.70–3.00m occurs too late to be effectively used over England.

S40.0 Sea War 1940

Naval Agreement

<u>1935</u>

In the naval agreement of 1935, in order to guarantee England's naval superiority necessary to maintain its empire, Germany commits to limit its naval force to 35 percent of England's capacity.

At the outbreak of the war, the German naval command cannot get involved in an open battle at sea. In response to the English blockade, it must limit itself to attack ships bringing supplies to England.

S40.1 "Seetakt" (DeTe). German Ship Radar l =82cm (9.1)

<u>September 1939</u>

At the outbreak of war all bigger German war ships are equipped with "Seetakt" devices built by GEMA to survey the sea and air space. The mattress antennas attached to a scanning range finder mount are characterized by a wide azimuth resolution and function over a range of 25km against big ships. They are, however, not accurate enough for gun laying.

S40.2 TypeY and 79Z. English Air Warning Radar l =7m (10.2)

<u>September 1939</u>

At the beginning of the war two English war ships are equipped with a device of the type 79Y for air surveillance. Another ship has an improved device of the type 79Z with a range of 100km against airplanes. It is used in Scapa Flow since this area is not covered by the Chain Home.

December 1939

Beginning in December, 40 devices of the type 79Z are delivered to the fleet.

War against Merchant Fleets

German submarines penetrate as far as the East Coast of the United States and cause heavy losses of supply ships that form convoys.

Iran

3 July 1940

The English destroy the French war fleet that traveled to Iran to avoid detection.

USA

September 1940

In September 1940 the US delivers 50 destroyers of an older model to England to strengthen their escort capability. In exchange England leases military bases in the West Indies to the US, thus marking the start of the decline of the British Empire.

S40.3 FuMB 1 "Metox R600A." German Warning Receiver l =1.88-5.00m

1940

In 1940, 1,100 units of the heterodyning receiver R600A developed by the Communications Research Institute of the German Navy are built by the French companies Metox and Gardin. Together with the receiver "Metox R203" (S40.2) [4 pg 107] and the array antenna "Sumatra" (S42.4.4) it is used as warning receiver and later with the big phase array antenna "Timor" (S42.4.7) on battle ships. [2 pg 167]

August 1942

Beginning in August 1942 it is also used as FuMB1 on submarines.

S40.4 Metox 8203. German Warning Receiver l =1.88-5.00m

The receiver type R203, also built by the French company Metox serves as addition to the receiver Metox R600A (S40.3) to increase the range to longer wave lengths.

S40.5 FuMB2 Sadir R87E. German Warning Receiver l =2.50-4.55m

1940

In 1949 the receiver FuMB2 built by the French company Sadir as type R87E is used by navy radar checkpoints. It is also supposed to be used as warning receiver on submarines. [1 pg 174]

S40.6 Olga 1 and 2. German Warning Receiver l =1.40-1.80m

1940

To be able to jam the transmitter Chain Home Low (CHL), the company GEMA develops the jamming station "Olga 1" in 1940. It has a wave range of λ=1.50-1.80m and a pulse power of PI.300W at a pulse frequency of 500, 700, or 900Hz and is used at the coast of the English Channel. The quantity production of the improved device "Olga 2" with a wave range of λ=1.40-1.80m and a pulse power of P=450W is performed by the company Blaupunkt. [2 pg 171]

L41.0 Air War 1941

Loan and Lease Agreement

<u>March 1941</u>

On 11th March 1941 England and the United States sign the loan and lease agreement. In November 1941 Russia signs it too. The United States delivers 3,000 tanks and 4,000 airplanes in the first year alone.

L41.1 "Lichtenstein." German Night Fighter Plane Radar l =9cm

<u>Summer 1939</u>

In summer 1939 the company Telefunken develops a radar altimeter. But the Air Force Ministry of the Reich shows no interest.[1 pg 105]

<u>April 1940</u>

When the need for a radar device for night fighter planes becomes evident, the radar altimeter is being rebuilt for this purpose and is ready for testing in a few weeks. The Air Force Ministry of the Reich insists that the antennas be mounted inside the airplane. By fall it becomes clear that it is impossible to fulfill this requirement. Then it takes almost another year until the radar, equipped with horizontally polarized antennas mounted outside the airplane and a range of 2-3km, is ready for operation.

<u>9 August 1941</u>

The first downing of an airplane with the "Lichtenstein" radar happens during the night of the 8/9 August 1941.[1 pg 113]

<u>22 June 1941</u>

Start of Russia Campaign

L41.2 "Würzburg-Riese" ("Würzburg Giant"). German Flak Gun Laying Radar l =54cm

In order to improve the range and accuracy of the "Würzburg" radar, it is upgraded with a parabolic mirror of 7.50m diameter and achieves a range of 60km.

<u>September 1941</u>

The first radar is used in Berlin by the flak. The total of 1,500 units produced soon take over the automatic fire control of the flak.

L41.3 "Himmelbett." German Fighter Aircraft Control

<u>End of 1941</u>

General Kammhuber starts to build a highly echeloned system of defense. It consists of fighter aircraft control centers equipped with a "Freya" device (L40.9.1), providing air surveillance thanks to its large range and great azimuth angle. Added to it are two "Würzburg-Riesen" (L41.2), one pursuing the enemy, the other guiding its own fighter planes. The "Seeburg-Tisch" provides an optical illustration of the overall situation. "Himmelbett," however, can only guide one fighter plane at a time and that only for a distance of 60km. Therefore two Y-lines (L40.8.1) are later added to the control station.[1 pg 156]

To cover the area of Skagerak, the cruiser "Togo" is being equipped as a hunter escort ship.

<u>End of 1941</u>

The importance of radar technology is being recognized and General Martini is put in charge of radar technology. His first action is to convene a conference of professors, thus establishing the contact between the military and academia which was lacking before. And all radar specialists positioned at the front can cooperate with industry under the program “Rü Funk Aktion.”

L41.4 “AI Mark VII.” English Night Fighter Aircraft Radar λ=9cm

November 1941

Devices coming from the production line are tested.

S41.0 Sea War 1941

German Submarine Production

Spring 1941

Efforts to increase the production of submarines result in the delivery of 10 submarines per month beginning in spring 1941. Development of radar devices of the English defense is also in full swing.

S41.1 Type 281. English Warning Radar for Ships λ=3.30m

The ship radar Type 281 developed and produced during 1940 has a pulse power of P=1000kW. It has a rotary antenna system with a duplexing receiving antenna which, with a wide azimuth angle, results in a bearing accuracy of ±1 degree. The range against airplanes is 110km, against ships 20km.

February 1941

Beginning in February 1941, the device Type 281 is used by the fleet as replacement for types 79Y and Z and remains the standard warning radar for large ranges until the end of the war.

S41.2.1 Type 284. English Fire Guiding Radar for Ships λ=50cm

After preliminary tests, an order for 200 devices with a pulse power of P=25kW and Yagi antennas is placed with the industry in April 1940. In June the order is increased to 900 units.

April 1941

The battle ship “Prince of Wales” is the first ship to be equipped with 11 radars. In the middle of May the heavy cruiser “Suffolk” was also equipped with these devices (S41).

S41.2.2 Improved Type 284. Fire Guiding Radar for Ships λ=50cm

During 1941 the Type 284 equipped with duplexing antennas reaches a bearing accuracy of about plus/minus 10 arc minutes. By increasing the transmission power to P=150kW and the degree of sensitivity of the receiver by a HF mixer, the range against ships is increased to 27km, against airplanes to 130km plus/minus 25m.

January 1942

The first devices are installed in HMS “Duke of York” to become operational in January 1942.

The device remains the standard fire guiding radar of the fleet until the end of the war.

S41.3 Type 289. Dutch Ultrashort Wave Gun Laying Radar

Two prototypes are developed in Holland and brought to England in May 1940. They are installed in stabilized gun mounts of Hr.Neth.M.S. “Isaac Sweers.”

S41.4 Type 286L. English Submarine Warning Radar λ =1.40m

In order to better protect the supply ship convoys coming from the United States against the successful operating German submarines, the escort destroyers are equipped with a modified aircraft Anti Surface Vessel (ASV) radar.

17 March 1941

On 17 March 1941 Captain Lieutenant Schepke discovers the surfaced submarine U100 and sinks it by ramming it. Soon afterwards Captain Kretschmer locates and sinks the U99. These radars, however, cannot locate submarines operating at periscope level.

S41.5 SC1W and SC2W. Canadian Submarine Warning Radar

ASV radar devices built in Canada are also used to spot submarines, but are not very successful.

S41.6 Types 271 to 274. English Submarine Warning Radar λ =10cm

To be able to locate submarines operating at periscope level, a radar for escort ships is developed that has a magnetron transmitter of several kW and a crystal modulator stage with a klystron oscillator. Separate rotating antennas for transmitter and receiver are mounted on a small, ocean-going cabin that can be installed on ships in a short time. The range against surfaced submarines is 5km, against submarine periscopes a good 1 km.

March 1941

In March the first installation is ready for operation, at the end of 1941, there are 25 installations operating on ships escorting convoys.

1942

The radars improved during the following year are called types 272 to 274.

Sinking of the "Bismarck"

The battle ship "Bismarck" leaves Gotenhafen to reach, together with "Prinz Eugen," the Atlantic by way of the Denmark Strait without being noticed.

21 May 1941

The Bismark is, however, discovered by the English cruiser "Suffolk," hidden together with the cruiser "Norfolk" in the fog banks of Iceland, with the help of the recently installed radar Type 284 (S41.1.2.1). Almost simultaneously the English are located by the "Bismarck's" two "Seetakt" devices. When the "Norfolk" appears from the fog for a short time, it is immediately fired upon. The English do not engage in a battle, but pursue the Germans during the night and call for the battle ships "Hood" and "Prince of Wales."

23 May 1941

"Hood" and "Prince of Wales" meet the Germans at dawn. After a battle of 15 minutes the "Hood" is blown out of the water and the "Prince of Wales," severely damaged, has to give up.

The "Bismarck," still being pursued, separates from "Prinz Eugen" and advances in a big circle toward the Bay of Biscay. At midnight the "Bismarck" is attacked by torpedo airplanes of the carrier "Victorious" equipped with ASV radar. They get one hit, but cause no great damage. Then the English lose radar contact.

The warning receiver of the "Bismarck" – probably Letox, Type R 203 (S40.4) – still receives the futile search pulses of the English – probably radar Type 281 (S41.1). Assuming that his

location is known, Admiral Lütjens sends a long radio communication. The English take a bearing on the "Bismarck," but calculate a wrong location so that the "Bismarck" escapes.

26 May 1941

In the morning of the 26 May 1941 the "Bismarck" is discovered by a Catalina flying boat equipped with an ASV radar. In the afternoon torpedo airplanes of the carrier "Arc Royal" inadvertently attack one of their own cruisers followed by an attack on the "Bismarck" whose rudder servo is hit. A night attack by English destroyers is discovered in time and beaten back by a barrage.

27 May 1941

Next morning the heavily damaged "Bismarck" is sunk by her crew after a heroic yet futile battle.

Africa Campaign

In the middle of February 1941, responding to a request for aid by the Italians, Hitler sends General Rommel and his army of tanks to Africa.

S41.7.1 ASV Mark II. English Radar for Sea Reconnaissance; l =1.50

In 1940, an improved version of the first radar for sea reconnaissance is goes into quantity production as ASV (Anti Surface Vessel) Mark II.

1941

Since 1941, the majority of airplanes of the coast commando are equipped with ASV Mark II. In the beginning of 1942, however, an official English report states that the devices are so prone to jamming that their efficiency is only 50 percent. By the end of the war, in the United States alone 7,000 units are produced and 10,000 units in Canada, largely to equip American airplanes.

S41.7.2 ASV Mark II Captured

June 1941

On board of a captured airplane (probably a Hudson bomber that made an emergency landing at Brest) the German Aviation Research Institute finds an ASV device.

Even though the "Bismarck" as early as May 1941 is equipped with warning receivers for λ=1.50m and 50cm, the Air Force Ministry of the Reich (Michelsen) is utterly surprised that the English already have radar devices for airplanes.

Although the captured device is severely damaged, it is repaired and operable, including a broken transmitter triode. It consists of a Yagi antenna as transmitter, a Yagi antenna directed diagonally ahead as receiver, one each for right and left, which pulse switch the phase, thus enabling an approach run. The first trial on the ground brings good results. When an airplane with strong sidelobes from the side antennas is captured soon afterward, it suggests that these sidelobes from the side antennas increase the range considerably. A flight test seems to make sense and Professor von Handel from the German Aviation Research Institute provides a Ju 52 for this purpose.

S41.7.3 Captured ASV Device Is Used

Fall of 1941

Yet General Martini orders that the installation be dismantled before the test, installed in a He111, and immediately dispatched without prior testing to Sicily to survey an enemy escort at night. The device works well and has a range of 150km at all sides against large targets at an

altitude of 3,000m so that at each flight provides surveillance of an area 300km wide. The He111 equipped with the ASV device is part of the special commando Koch of the LN experimental range Köthen and it is this single airplane that takes care of all night-time surveillance in the Mediterranean (S42). Not before the end of 1942, just as the first airplane is damaged at an emergency landing after being hit by a fighter plane, a second He111 equipped with the English ASV is ready for action. At the beginning of 1943 the He111 it attacked by a night fighter plane while making a landing in Trapani, Sicily, and burns up.

S41.8 Loran (Long Range) US Navigation Procedure l =160m

1941

Loran is a navigation procedure for great distances. Two transmitters at a great distance from each other send 45µs pulses synchronized over the ground wave. The cycle time difference on course is a hyperbola. The second on course is provided by a second measurement with a second pair of transmitters. The range is 1600km, the accuracy plus/minus 4km.

Because of the strong damping of the ground wave over land the procedure can be used only at sea.

S41.9 Rostock. German Onboard Radar for Marine Reconnaissance Planes l =2.40m

The company GEMA develops an onboard radar for marine reconnaissance.

Japan

7 December 1941

The Japanese attack the US fleet at Pearl Harbor and inflict severe damage.

United States

11 December 1941

After the Japanese attack on the US fleet, Germany and Italy declare war on the Americans who through their massive support for England have been threatening Germany for a long time.

L42.0 Air War 1942

L42.1 Wismar Progam

27 February 1942

An English assault party captures the steering part and the antenna head of a “Würzburg” installation. This is how the English find out that its frequency cannot be changed.

September 1942

As a preventive measure, the German radar devices are changed step by step to variable frequencies: “Freya” λ=2.30-2.50m, “Würzburg” λ=54-61cm, “Seetakt” λ=70-120cm.

L42.2 Chaff Tests

The German Aviation Research Institute (DVL) shows that a reflected star suspended from a parachute in a “Würzburg” device looks like an airplane but is quickly recognized as a deception because it does not move.

1941

At the Baltic Sea Telefunken carries out tests with reflected stripes. Göring orders all test to be stopped immediately to prevent betrayal.

March 1942

The English also carry out tests with chaff and keep them secret.

L42.3.1 GEE. English Hyperbola Procedure l =6m (4-16m)

In England, three transmitters placed at great distance from each other send out synchronous pulses. To distinguish the pulses, they are sent one after the other at small, known intervals. The cycle time difference established with an onboard oscilloscope of the receiver R1335 shows a hyperbola on course for every two transmitters. The accuracy of the intersection is between 100 and 500m.

13 August 1942

After a trial run in August 1941, 80 scouts equipped with GEE radar are used at an attack on Essen.

Lübeck

28 March 1942

The night attack on Lübeck that destroyed the better part of down town is the beginning of the war on the general population with the goal to eraticate the cities through carpet bombing.

Cologne

30 March 1942

Scouts lead 1,000 bombers equipped with GEE to Cologne.

L42.3.2 R1335. English GEE Receiver

Even though the English deploy a J system corresponding to the "Knickebein" to camouflage the GEE, the GEE procedure's mode of operation is soon found out by the group for captured devices of the German Aeronautic Research Institute with the help of a R1335 receiver captured near Essen.

L42.3.3 "Heinrich" 1 and 2. German Jamming Transmitter l =4-14m in Four Ranges

November 1942

"Heinrich" installations, initially developed by the Central Post Office to jam the English coast radar installations, are now used to jam GEE. The installation consists of two transmitters with a power P=500W ("Heinrich" 2 P=1.5kW) and a common part of the network. The modulation occurs with a 200kHz sine frequency and an additional 100Hz mains hum. At the end of the war, 279 devices are in operation. (See also Jamming Transmitter "Feuerstein," L44.7.4)

L42.3.4 R1355. English GEE Receiver

To avoid the jamming efforts of the Germans, the English use a different receiver Type R1355 that is switched in the last phase of the approach to a second frequency for the attack.

L42.4 "Mannheim." German Flak Guiding Radar l =52-64cm

The power of the “Würzburg” device (L49.1) with a 3m mirror is considerably increased by a higher transmitting power and a more costly electronics. With a range of R=30km, the accuracy for distance is ΔR=10m and the azimuth resolution is $\Delta\alpha$=0.15 degrees.

The “Mannheim” is able to pursue targets automatically once contact is made. A further development of this type is “Ansbach” with a mirror diameter of 4.50m.

L42.5 “Rebecca-Eureka.” English UHF Beacon l =1.25-1.75m

The UHF beacon “Bureka” is developed for the purpose of supporting parachutists and under cover agents. Airplanes equipped with the “Rebecca” can make an instrument approach to an assigned fix.

The radar beacon “Eureka” consists of a small heterodyning receiver with a transmission that sends an answering pulse for every pulse it receives. A battery powered transformer provides the power supply. The “Eureka” also has an ASV device Mark I, additionally equipped with the device “Rebecca.”

Summer 1942

After testing prototypes of a few units of R/E I, the Type R/E II is developed in Summer 1942. It has five frequencies to choose from. The beacon “Eureka II” runs for six hours and can serve 40 airplanes simultaneously. At a later time the beacon Type E II is replaced by the lighter Type E that operates with American miniature tubes and can be fastened to the parachutist’s belt. Several other versions are developed for special purposes, e.g., the Type Babs II used on a small truck. It is positioned at the runway and marks the approach path with its duplexing thermal characteristics.

L42.6.1 “Moonshine.” English Transmitter to Simulate Airplanes

1942

The jamming transmitter “Moonshine,” developed by the English in 1942, operates on the wave length of the “Freya” installation λ=2.40m (L43.3).

The pulse received by the receiving section and rectified is multiplied by a Multivibratorschaltung – similar to the German procedure “Garmisch-Partenkirchen” (L40.3.5) – and then sent out again by the transmitting section so that it simulates a group of airplanes.

To keep up the deception, the “Freya” frequency has to be monitored constantly to quickly adjust to each change in frequency.

17 August 1942

It is first deployed in August 1942 at an attack of American airplanes on Rouen.

L42.6.2 AN/APQ-15 “Moonshine.” American Transmitter to Simulate Airplanes

The English “Moonshine” device is later replaced by the Type AN/APO-15 developed by the Americans.

It consists of a broadband receiver that excites a liquid-filled ultrasound cell with the intermediate frequencies of the received pulse in the range of 18MHz. The ultrasound cell takes the repeatedly reflected pulse back again and sends it out after changing the frequency. In this way the device automatically adjusts to each change in frequency and amplitude.

20 December 1942

At the end of 1943, 200 units with three exchangeable high frequency parts each that cover λ=1.85-3.40m are ordered and delivered a year later.

L42.7 “Wassermann” (“Aquarius”). German Ground Radar λ=2.40m

To increase the range of the “Freya” device (L39.3), the Freya are equipped with a tall, highly focusing antenna. The installation called “Wassermann” attains a range of 300km.

L42.8 “Karl” 1 and 2. German Jamming Transmitter λ=1.20-3.30m in Four Ranges

Because there is only one transmitter available in the 2m range, the 30W transmitter “Caruso” (L40.10), the “Karl” transmitters are developed. “Karl 1” has a power of about 400W and is modulated with a frequency of 150kHz.

The power of “Karl 2” is 2kW.

To jam the enemy radio communication (λ=2.00-3.30m), two transmitters powered by a common part of the network are modulated by sawtooth oscillation.

150 units were delivered.

S42.0 Sea War 1942

S4.1 FuMe1 “Wespe” (“Wasp”). German IFF λ=75-83cm

1942

The German battle ships are equipped with the IFF “Wespe,” to be recognized by the “Seetakt” radar as friendly ships. The next generation, “Wespe g2,” has an alternating frequency modulation of an expanded range of λ=70-85cm.

12 February 1942

Campaign “Donnerkeil”

On the 11th of February close to 11 p.m. the German battle ships “Scharnhorst” and “Gneisenau,” as well as the heavy cruiser “Prinz Eugen leave the port of Brest and take curved course to the East. During the same night, two He111 start out with five jamming transmitters “Garmisch-Partenkirchen” (L40.3.5) each. Each of these transmitters sends out five jamming pulses for each received pulse so that an attack on Brighton is simulated while bomber formation attack the airports around Plymouth.

Since the ships have to observe radio silence in order not to be discovered, their location is pinpointed with the aid of “Seetakt” radar (S40.1) positioned for this purpose of the Coast of the English Channel. The results, however, are wrong or late. The receivers of IFF “Wespe” (S42.1) installed at the “Scharnhorst” are supposed to provide bearing lines to the location of the “Seetakt” radar. They fail. Therefore the course has to be followed by the old method of traverse sailing.

Since the English expected the German ships to leave harbor, they reinforce their air reconnaissance with three lines. The ASV radar fails with the first two lines, at the third the ASV radar is employed after the ships had already passed the line.

This way the bomber formation gets as far as Le Havre and enters the range of “Chain Home.” At this point all available jamming stations at the coast of the English Channel are switched on so that the English, who have no knowledge of the ships, expect a heavy air attack.

They are discovered shortly past noon by a not yet jammed 10cm radar Type 271 (S41.6) when the Germans are already outside the reach of the remote locking around Dover. Then the

English keep attacking the Germans until dusk, but without success. At the Dutch Coast the ships are hit by two mines, yet are able to reach their home port under their own power.

S42.2 "Leigh-light." English Procedure for Night Attacks

To fight submarines at night the English initiate the Leigh-light procedure. Squadron Commander Leigh proposes not to switch on the floodlight of the attacking airplane until the last phase of the approach when it is automatically switched on by a signal of the ASV installation. The submarines, which must surface during the night, suffer a complete surprise attack and high losses.

S42.3 FuMB 1 "Metox R600A." German Warning Receiver l =0.60-2.60m

To protect submarines from surprise attacks by AVC airplanes, they get the receiver "Metox R500A" (S40.3) or "Sadir R97E" (S40.5) that sounds a warning when search pulses hit it.

Because time is short, the receiver is operated with the antenna "Honduras" (S42.4.2). It is later replaced by the solidly mounted "Bali" antenna (S42.4.3) At the same time a visual display is introduced to replace the nerve-wracking warning sound.

S42.4.0 German Ship Antennas for the Range of 1.50m

S42.4.1 FuMB Ant 1 "Hondo"

"Hondo" is a simple array antenna used by torpedo speed boats. It has an eight-shaped characteristic and must be rotated constantly.

S42.4.2 FuMB Ant 2 "Honduras" ("Biskayakreuz")

The "Honduras" antenna planned for submarines consists of two horizontal arrays of different lengths flexed downward that are hand held and taken into the submarine before submersion. Because of its eight-shaped characteristic it also must be rotated constantly.

S42.4.3 FuMB Ant 3 "Bali" ("Häschen") Round Antenna

The solidly mounted, sea-worthy "Bali" antenna consists of a broadband, horizontally polarized array that has two additional vertical rods to receive the vertically polarized waves, thus the name "Häschen" ("Bunny"). The "Bali" antenna has a circular radiation and a range of λ=0.75-3.00m.

S42.4.4 FuMB Ant 4 "Sumatra" Array Antenna

<u>Beginning of 1943</u>

The "Sumatra" antenna is a broadband dipole. It has flat, drop-shaped branches mounted in front of a reflecting area. In order to receive horizontally as well as vertically polarized waves, the dipole is tilted**.** Its reception angle is ±50 degrees.

To be able to survey the whole area, the antennas of the "Sumatra" installation are mounted on all four sides of a ship.

S42.4.5 FuMB Ant 5 “Samoa” Phase Array Antenna

The “Samoa” antenna has two broadband, flexed [see “Sumatra” (S42.4.4)] dipoles mounted side by side and tilted so that they enable a minimum direction locating.

S42.4.6 FuMB Ant 6 “Palau” Phase Array Antenna

The difference between the “Falau” phase array antenna and the “Samoa” antenna is the bigger reflector of the former. Its bearing resolution is ±2 degrees. It has a wave range of λ=0.90-2.50m.

S42.4.7 FuMB Ant 7 “Timor” Phase Array Antenna

“Timor” is a heavy phase array antenna that can be used only on big ships. Eight vertical and four horizontal broadband dipoles result in a bearing resolution of ±1.5 degrees.

S42.5 FuMB 4 “Samos RS1/5 UD42.” German Warning Receiver l =0.64-3.33m

The heterodyn receiver “Samos,” developed for the Navy by the company Rohde and Schwarz, has a sensitivity of about 10µV. It replaces the older types “Metox R600A” (S40.3) and “Metox R203” (S40.4), as well as type “Sadir R87E” (S40.5). Beginning at the end of 1943, the company Lorenz also builds it for the Air Force.

S42.6 Fub1B5 “Fanö.” German Warning Receiver l =38-75cm

The receiver “Fanö,” also developed by the company Rohde and Schwarz, has a wave range of λ=38-75cm and a wave range of λ=19-38cm with the upper beam wave of the oscillator.

S42.7 HF-DF (“Huff-Duff”). English Short Wave Visual Direction Finder

The English introduce a short wave direction finder that indicates the direction on an oscilloscope so that the direction can be determined even with very short radio communications of submarines. First locating the direction is done from land stations, beginning Fall 1942, it can also be used from escorts for convoys.

S42.8 “Kobold 2 and 3.” Geerman Jamming Transmitter l =1.20-1.80m

The jamming transmitter “Kobold,” developed by the Central Post Office to jam the ASV aircraft used for sea reconnaissance has a power of P=60W, a wave length of λ=1.20-1.80m, and is modulated with a board frequency of f=500Hz. The type “Kobold 3” has a power of P=120W with all other specifications unchanged.

When General Rommel is close to El Alamein, the escort convoy providing supplies for him are located by English ASV aircraft and attacked. To prevent this, Dr. Scholz from the Central Post Office suggests to use airplanes of the special commando “Koch,” equipped with “Kobold” to jam the English ASV aircraft. Professor v. Handel, however, is afraid that this has the opposite effect.

2 November 1942

A test flight with a German ASV airplane is scheduled for 2 November 1942. It proves that the transmitter can jam the approximate location of ships at great distances, but cannot prevent their being spotted at short distances. The jamming project is immediately abandoned.

The Allies Land in Algiers

On 7 November 1942 the German day reconnaissance aircraft report that an enormous escort convoy that had assembled during the previous days in Gibraltar left the port heading east. The special commando “Koch” at KG100 gets the order that its ASV aircraft keep in touch with the escort convoy at night and report its respective location. But nothing can be found in the quadrants calculated on the map assuming that Malta is the destination of the convoy. Acting against the explicit order, the aircraft continues westward and discovers that the escort convoy had turned around during the night and is preparing to land in Algiers. The discontinued radio communication are received by the omni bearing selector, OBS, but nobody believes them so that the landing can be accomplished completely undisturbed.

S42.9 “Hohentwiel.” German Onboard Radar for Distance Reconnaissance Planes l =54cm

December 1942

The German distance reconnaissance planes are equipped with the radar “Hohentwiel,” developed by the Lorenz Company for sea reconnaissance. The radar operates at a wave length of λ=54cm.

L43.0 Air War 1943

Stalingrad

1 January 1943

After a desperate battle, the German army enclosed in Stalingrad must capitulate.

L43.1 English Transmitter to Jam German Radio Communication

The condition of the air space over England forces the Germans to shift to night attacks. The fighter bombers Fw 190 guided by a direction finding, DF procedure are directed to their target by ultrashort wave radio communication. In response, the English use jamming transmitters that completely shut down any radio communication after June 1943.

L43.2 FuMB/H “Domeyer.” German Ultrashort Receiver l =1.00-1.50m

The series of the “Domeyer” receivers with types A and B (λ=3-12m), Type C=FuMB 3 (λ=1.35-1.75m) developed in 1942, as well as types F and G (λ=1.20-4.00) is expanded by Type H (λ=1.00-11.50m). It is a heterrodyn receiver with a sensitivity of 4µV and a band width of ±150kHz.

L43.3.1 “Oboe I” (“Bumerang”). English Navigation Procedure l =1.20-1.40m

At the beginning of 1943 the English deploy “Mosquitos,” light, fighter planes flying at an altitude of 10,000m that cannot be attacked by either flak. They locate their targets with the help of the “Oboe” procedure that has a range of 400km at this great altitude. With the “Oboe” procedure the airplanes send a response pulse with a somewhat different frequency to every pulse received from the ground receiver “Katz.” The ground station calculates the distance from the cycle time and, with the help of an additional pulse, transmits the calculated deviation from the estimated distance to the airplane where it is turned into audible dot and dash signals, respectively. When receiving continuous dash signals, the airplanes moves in a circle around the ground station. When approaching the target, the airplane receives four go-ahead signals and then the signal to release the bomb from the second ground station “Maus” that operates on the same wave length as the ground station “Katz” but with a different pulse sequence frequency. The bomb release lever turns off the onboard transmitter and advises the ground station of the point of release. The accuracy of hitting the target with “pinpoint bombing” is ±100m.

<u>31 Decembeer 1943</u>

After an attack on the “Gneisenau” in the harbor of Brest and on a night hunter control station in Belgium, the “Oboe” procedure is first used at an attack on the Ruhr District on 31 Dezember 1942. Since the “Oboe” procedure can guide only one airplane at a time, the English, beginning in March 1943, use “Mosquitos” as scouts that mark the target for the following bomber formation with flare bombs.

L43.3.2 Reconnaissance of the “Oboe” Procedure

<u>August 1941</u>

Only when the surveillance station Kettwig on the Ruhr gets a receiver “Domeyer H” (L43.2) in August 1943, the signals of the “Oboe” guiding stations are received and interpreted correctly.

November 1943

Confirmation comes at the beginning of November 1943 when the time connection between the signal and the release of the bomb is established.

In order to give warning of “Mosquito” attacks, a “Wassermann” installation (L43.2) is built that, in cooperation with the “Domeyer” receiver (L43.2), can accurately identify the target based on the “Oboe” signals a few minutes before the attack.

L43.3.3 Boomerang Jamming Attempts

Even though the officials do not take the report of the surveillance station Kettwig seriously, General Martini provides 15 jamming transmitters “Karl” (L42.8) in the middle of November 1943. Their deployment is unsuccessful.

Fall 1943

In late fall 1943 the Ln-Vers-Rgt Köthen puts up a makeshift installation near Duisburg that has a receiver and a pulse transmitter for “Oboe” frequencies.

When “Mosquitos” approach, the receiver is modulated to their frequency. Then a transmitter is activated and its frequency continues to be adjusted until the aircraft answers its pulses. These pulses are then amplified and switched for modulation on the transmitter. This creates a feedback loop that keeps building up the pulse frequency until the power of the onboard transmitter crashes and makes navigation impossible.

7 January 1944

In spite of these clear-cut results, the effect of the “Oboe” procedure is not officially recognized until after a “Mosquito” captured in January 1944 is examined. Only now an order is placed for 20 anti-boomerang devices.

L43.3.4 Anti-Boomerang A1. German Jamming Transmitter l =1.20-1.50m

June 1944

Beginning in June 1944, the company Lorenz produces anti-boomerang A1 installations in quantity having a pulse power of 25kW and functioning according to the ball principle (L43.3.3).

L43.3.5 Anti-Boomerang A2. German Jamming Transmitter

The anti-boomerang A2 installation, also produced by the company Lorenz, does not use the ball principle.

The 80kW pulse transmitter “Eibsee” with an adjustable frequency range between 0.1-50kHz is deployed instead.

L43.4.1 “Jagdschloß.” German Ground Panorama Radar l =1.20-2.40m

The panorama procedure with its rotating and sharply focused beacon combines, in a single device, the otherwise contradictory requirements of great bearing accuracy and wide azimuth angle.

The “Jagdschloß” installattion (“Sternschreiber”), built by the company Siemens, operates with wave lengths in the range of λ=1.20-2.40m. To achieve sharp focusing, it is equipped with an 11m wide rotating antenna. Given favorable conditions, airplanes can be located at a distance of 300km.

Fall of 1943

In the fall of 1943 two “Jagdschloß” installations are operating, one in Tremmen (40km away from Berlin) and a second in Werneuchen. The images taken by them are transmitted automatically by microwaves to the command bunker at the Berlin Zoo. The fighter aircraft control stations “Himmelbett” (L41.3), are no longer useful to fight mass attacks, and are therefore superfluous.

L43.4.2 English Jamming Transmitter l =2.40m

To jam the German early radar warning station “Freya” and its successors “Tammut” and “Wassermann” (L42.7) that operate on the 2.40m wave length, the English develop corresponding ground and aircraft jamming transmitters that measure the “Freya” frequency in a short transmitting pause and automatically change their jamming frequency when the “Freya” frequency

changes. They are successfully employed during the night of 24/25 July 1943 at the attack on Hamburg.

L43.4.3 AN/APT2 Carpet I. American Jamming Transmitter l =2.40m

The Americans build the onboard jamming transmitter “Carpet I” that jams the entire frequency range of the “Freya” radar by noise modulation (carpet).

L43.5.1 Carpet II. American Onboard Jamming Transmitter l =54cm

The jamming transmitter “Carpet II” developed by the Americans is used to jam the “Würzburg” radar. Its oscillator is mechanically swept at a speed of 10MHz/sec over the entire frequency range of the “Würzburg” radar. To pinpoint the “Würzburg frequency accurately, the pulse frequency of the “Würzburg” and of the oscillator are directed in parallel over two beams with different bandwidth whose ouput voltage is cross switched. When the oscillator gets close to the “Würzburg” frequency, the then predominant voltage of the narrow beam turns off the sweep motor. At the same time the oscillator frequency is switched to an amplifier and after being modulated with a noise voltage it is sent out as jamming for 30 seconds. Then the search period is repeated.

Altogether 24,000 units of “Carpet II” are built.

L43.5.2 German Measures to Dejam the “Würzburg” l =54cm

After the implementation of the “Wismar” program (L42.1) one can dodge the jamming transmitters by changing the frequency until the time when the enemy uses transmitters that automatically follow each change of frequency.

With the make-shift procedure “Stendal A” the deflector is switched off. By foregoing measuring the distance, one can take a bearing on the direction and height of the jamming aircraft and adjust the searchlights accordingly.

With the procedure "Stendal B" the dial is only lit when the receiving signal is at its minimum since at that point the antenna is vertical to the polarization direction of the jamming agent. It reduced the jamming effect by a factor of ten.

With the procedure "Goldammer" this process happens automatically. The RHF procedure deals with noise interference of the time line of the receiving pulses instead of deflecting it. Periodically the time line is moved vertically so that the return signals appear in a vertical line one above the other while the irregular noise pulses are spread over the whole area.

L43.6.1 Window (Chaff). English Smoke Screen Procedure l =54cm

26 June 1943

Since the German Air Force is pushed into a defense position and the American aircraft search radar "AI Mark X" (λ=3cm) is available, Churchill decides the time to deploy Windows (L42.2) is here and on 26 June 1943 places an order to mass produce Windows with a wave length of 54cm.

25 July 1943

Window is first used during the night of 24/25 July 1943 at a massive attack of 800 bombers on Hamburg. Since the "Würzburg" devices are almost completely blinded by 92 million windows, the flak is powerless. Even the night fighter planes cannot attack because neither the "Würzburg" radar nor the "Freya" radar disabled by jamming transmitters on board the bombers can guide them to the bomber convoys. The "Lichtenstein" radar does not help them either since it is also compromised by the Window smoke screen. This is why the English lose only three airplanes at the devastating attack at Hamburg. At the three further attacks in July 1943 the losses remain below 3 percent.

August 1943

Beginning at the end of August 1943 the following massive attacks are expanded to Berlin.

L43.6.2 "Würzlaus." German Procedure to Clear up the Window Effect

To recognize airplanes in a cloud of chaff, the "Nürzburg" devices get an ancillary device, "Würzlaus." It has a steering transmitter forcing the pulse transmitter to operate on the same phase level. The chaff cloud appears on the screen as a slightly wavy deflection because of its small movements, while a fast moving airplane creates a different deflection with each pulse because of

the Doppler effect thus resulting in an image resembling a washed-out louse. To create the same smoke screen effect as with devices without “Würzlaus,” the amount of dropped chaff would have to be tripled.

September 1943

The first “Würzlaus” ad-ons are delivered in the middle of September 1943.

L43.6.3 “K-Laus.” German Procedure to Clear up the Window Effect

In the noise suppression procedure “K-Laus,” developed by the company Telefunken (Kettel), the image signal is amplified by two identical channels. Since a cycle time chain with a delay of 2µs is switched before one of the channels, all signals that do not change during that time cancel each other out, so that only the signals of the fast moving airplanes remain.

Together with further clever technical tricks, such as compensation of the chaff’s wind velocity (Wind “Louse”), the automatic fine tuning at the change of frequency (key “Louse”), an automatic control to achieve optimal pulse height, etc., a procedure evolves that provides effective noise suppression by chaff even with strong smoke screens.

Summer 1944

After tests in summer 1944 the procedure is not used until the end of the war.

L43.7.1 H2S (“Rotterdam”). English Onboard Panorama Radar l =9.1cm

The H2S panorama radar (code name “Home Sweet Hone”) has a magnetron that produces a pulse power of P=50kW with a wave length of λ=9.1cm. Its parabola antenna has horizontal polarization and rotates at 60rpm. The panorama image is projected on a CRT. At a test flight in October 1941 a test device developed for night fighter planes shows a recognizable image of Southampton.

August 1942

In August 1942 the device is ready for production and its prompt installation in bombers is ordered. During the night of 30/31 January 1943 bombers equipped with H2S radar are used as scouts of the attack on Hamburg.

February 1943

During the night of 2/3 February 1943 a radar with the test number 6 is captured in Rotterdam.

Research Team "Rotterdam"

Just two weeks before the "Rotterdam" device is captured, the opinion prevails at a conference of professors in the middle of January 1943 that wave lengths in the cm range are useless for radar technology.

<u>22 February 1943</u>

Then at the end of February General Martini founds the research team "Rotterdam." Finally the prohibition to do research in the field of cm wave lengths is lifted. An order is placed for a warning receiver of 9cm. A "Rotterdam" device is put together from captured debris and German parts that is operational in June 1943 and ready for testing.

L43.7.2 FuMB 7 (FuG350) "Naxos I." German Warning Receiver l =8-12cm

The receiver consists of an antenna mount and a six-leveled broadband NF amplifier. The antenna mount is formed by a λ4 (finger) antenna with built-in band pass that is later omitted, and a detector. Even though it proves difficult to make a stable detector, the company Telefunken succeeds in producing the first prototype in the middle of March 1943.

<u>June 1943</u>

At the beginning of June 1943 a series of 100 units is delivered. They have a sensitivity of 2000 kTo and attain a range off 10-20km.

and attain a range off 10-20km.

<u>End of 1943</u>

At the end of 1943 a series of 1,000 units is produced.

L43.7.3 "Naxos W." German Direction-Finding Receiver l =8-12cm

<u>August 1943</u>

Instead of a simple finger antenna the "Naxos W" receiver has a A/2 Yagi antenna attached to a 60cm mirror so that it can be used for direction finding. In addition, the receiver power is substantially improved.

L43.7.4 "Naxburg." German Direction Finding Receiver λ=8-12cm

<u>22 September 1943</u>

In spite of the strict order not to make any changes on radar devices, Colonel Dahl installs a 9cm receiver head on a 3m "Würzburg" mirror to increase the bearing accuracy and range of the "Naxos" receiver and achieves a bearing accuracy of ±1 degree and a range of 200km.

After that about 20 "Naxburg" direction finding receivers are built that attain a range of 400km if optimally placed. Using cross bearings or with improved bearing accuracy improved to 1/4 degree and the known altitude, the distance can be established with an accuracy of 10 percent. When the enemy uses the 3cm "Panorama" devices, it becomes evident that even this wave length, that is the third harmonic representation, is accurately received by the "Naxburg."

L43.7.5 FuMB 11-15 and 17 "Korfu." German Warning Receiver λ=1.7-18cm

The company Blaupunkt develops the heterodyning receiver "Korfu 812" that uses a magnetron as oscillator and has an accuracy of 500 kTo at a range of λ=8-12cm.

<u>June 1943</u>

It is deployed at the beginning of June 1943. In fall 1943, 15 direction-finding stations "Fu Peil A100 Korfu" with the receiver "Korfu 812" are deployed. With a rotating horn antenna they can locate "Rotterdam" airplanes at a distance of several 100km with an accuracy of ±4 degrees.

In 1944 two more types FuMB 14-15 with a range of λ=2.7-6cm using the upper wave of the magnetron as oscillator frequency are added to the three types of the "Korfu" series FuMB 11-13 with a range of λ=6-18cm.

<u>1945</u>

In 1945 the series is expanded by the Type "FuMb 17" and "Korfu 1726," respectively, with a wave range of λ=1.7-2.6cm.

L43.7.6 "Roderich." German Jamming Transmitter λ=7.5-10.5cm

February 1943

Right after capturing the first “Rotterdam” device, the building of a jamming transmitters for installation in airplanes is ordered in February 1943. In fall 1943 the company Siemens delivers the jamming transmitter “Roderich” modulated with 100kHz (navy code name: FuMS 11). Since its pulse power is only 4W, its use in airplanes is out of the question. It is used on the ground in several places that can be identified especially well by the “Rotterdam” radar and therefore used by the English as orientation aids.

L43.8 Berlin.” German Panorama Radar λ =9cm

After successful tests with the again functioning “Rotterdam” radar, the development of a German 9cm Panorama (Plane Position Indicator, PPI indicator) radar called “Berlin” is begun.

End of 1943

At the end of 1943, the pilot unit locating airplanes with its “Mannheim” mirror at a distance of 30km is ready.

L43.9.1 FuG 217 “Lichtenstein.” German Night Fighter Radar λ =3.30m

August 1943

In August 1943 the night fighter aircraft radar “Lichtenstein” (L41.1) is replaced by “Lichtenstein SN2. Thanks to its larger wave length of λ=3.30m and a vertical polarization, its azimuth angle is 110 degrees. Its pulse power of 2kW results in a range of 0.2-8km.

With this radar the night fighter aircraft is able to locate and attack the target once it is guided to the bomber convoy. Since the English possess no jamming devices for the wave length of 3.30m, the German night fighter planes’ hit success rate increases and exceeds the 10 percent limit in Spring of 1944. Thus the English are forced to stop their massive attacks.

L43.9.2 “Tuba.” American Ground Jamming Transmitter

To jam the German night fighter plane radar “Lichtenstein,” the Americans build the ground jamming transmitter “Tuba,” that has a power of 50kW.

L43.10.1 "SS-Loran." American Navigation Procedure

The SS Loran procedure (Skywave Synchronized Long Range) is a hyperbola procedure that works on the same principle as the "Loran" procedure (S41.8) except that the synchronization of the transmitters occurs on the n layer. Therefore it can be used only at night when the E layer is constant. On the other hand, it has a very great range.

<u>1943</u>

After the allies have landed in Africa, they build an SS Loran system that covers all of central Europe and a big part of the Mediterranean. The pair of transmitters that are part of it are located in Oran-Deran and Scotland Tunis.

<u>Mid 1944</u>

A severely damaged onboard receiver is captured in mid 1944. The German Aerautic Research Institute discovers its mode of operation without great difficulties because maps with the hyperbola lines are found in the captured receiver.

L43.10.2 "SS Loran" Jamming Transmitter

<u>March 1945</u>

To jam the "SS Loran" procedure, a dozen 1kW transmitters with noise modulation are deployed in March 1945. Since their jamming range is only 50-100km, the Central Post Office develops a powerful jamming transmitter that sends synchronized pulses. But it is finished too late to be used in the war effort.

L43.11 "Shoran" (Short Range). English Hyperbola Procedure λ =1m

"Shoran" is a hyperbola procedure that, like the "Loran" procedure (S41.8) is based on measuring the difference of the cycle time, yet uses in the ultrashort wave range. It is not often deployed since other navigation procedures are available.

S43.0 Sea War 1943

S43.1 FuMO 30. German Submarine Radar

<u>Beginning of 1943</u>

At the beginning of 1943, submarines get the radar device" FuMO 30" developed by the company GEMA.

S43.2 "FuMO 61 Hohentwiel U." German Submarine Radar

Later the device "FuMO 30" is replaced by the submarine radar "Hohentwiel U," built by the company Lorenz, which has a rotating mattress antenna.

S43.3 ASV Mark III. English Aircraft Panorma Radar l =9.1cm

Beginning in spring 1943, the English use their H2S panorama radar as ASV Mark III also in aircraft for sea reconnaissance, a fact the Germans don't find out before fall 1943. In spite of equipping the submarines with the Metox warning receiver (S42.3), the increasing losses of submarines necessitates abandoning their use almost altogether between Spring and September 1943.

July 1943

When it is found out that the oscillator of the Metox receiver sends out a betraying beam and is therefore responsible for the submarine losses, its deployment is ceased at the end of July 1943. Even though the possibility to locate the Metox beam existed (S44.2), the English, according to their own records, did not take advantage of it. The real cause for the heavy losses was, however, different: The Leigh-light procedure (S42.2) enabled night surprise attacks. With the High Frequency – Direction Finding (HF-DF) visual direction finder (S42.7) even very short radio communications of the submarine could be located.

Since the Allies broke the German secret code, they knew the location of the submarines at certain times. The escort ships of the convoys had been equipped with the 10cm radar Type 271 (S41.6) for which the submarines had no warning receiver.

There is also no warning receiver available for the 9cm panorama radars used at that time in reconnaissance airplanes.

The Allies Land in Sicily

10 July 1943

In the middle of June the Allies land in Sicily.

S43.4 FuMB 7 “Naxos 1.” German Warrning Receiver λ=8-12cm

<u>September 1943</u>

To counteract the gcm radars that are being used more and more, in September 1943 the submarines are equipped with the “Naxos” receivers (L43.7.2) of the first production run even though they are not suited for use in submarines. The finger antenna must be held tilted, turned by hand, and taken into the submarine before submersion. The radar’s range is only 8km, but it is greeted as a welcome aid.

S43.5 FuMB 8W/9W “Cypern I/II.” German Wave Length Indicator λ=1.20-1.90cm

<u>September 1943</u>

To define direction and wave length of received signals, the submarines get the wave length indicator FuMB built by the Hagenuk Company. Its oscillator undergoes constant alternating frequency modulation so that the wave range λ=1.20-1.90cm is always closely watched. Because the type “Cypern I” tends to give false alarms due to feedback, it is replaced by the type “Cypern II.”

The wave length indicator can be connected to either the “Bali” antenna or to the minimum phase array antenna “Samoa.” Like the “Palau” antenna, it consists of two butterfly-shaped broadband dipoles, that are switched against each other and mounted in front of a reflector. In order to be able to receive horizontally as well as vertically polarized signals the dipoles are tilted. In the submarines, the backside of the on-board radar antenna (S43.2) serves as reflector.

S43.6 FuMB “Borkum I/II.” German Warning Receiver λ=0.75-3.00cm

<u>September 1943</u>

In September 1943 the submarines are equipped with the warning receiver “Borkum I.” It is a simple detector/receiver with a broadband NF amplifier. Thus its frequency range depends on the antenna used.

Since the detector is often disrupted by the short-wave signals of its own on-board transmitter, in the type “Borkum II” it is protected by a high-pass filter connected in series. Using a “Bali” antenna (S42.4.3) it has a range of λ=0.75-3.00cm.

S43.7 FuBM 24 “Cuba I” (Fliege). German Direction-Finding Receiver l =8-23cm

<u>End of 1943</u>

At the end of 1943 the receiver head “Cuba I” developed for the Marines is available in greater numbers. It consists of a broadband tilted $\lambda/2$ array antenna mounted on a parabola dish. It increases the range of the “Naxos” receiver (S43.4) to 20km and results in a bearing accuracy of ±10 degrees with an azimuth resolution of 110 degrees. It is used in surface ships. When used in submarines, the antenna head is clamped to the rotating loop antenna and must be taken into the submarine when it dives.

S43.8 Type 277. English Multipurpose Ship Panorama Radar l =10cm

The English develop a 10cm panorama radar for ships that has a rotating antenna and a CRT as plan position indicator.

It is used as aircraft warning receiver on ships. When used as gun laying device on big ships, it has a big antenna mounted on a stabilized platform and can be pivoted around the vertical and horizontal axis by remote control so that the altitude can also be measured. It serves as fighter aircraft control for aircraft carriers.

Sinking of the “Scharnorst”

<u>25 December 1943</u>

Because the "Tirpitz" is damaged, the "Scharnhorst" leaves the Altenfjord port at the North Cape by herself on 25 December 1943 in order to attack a escort convoy reported by the German marine reconnaissance.

By intercepting a short radio communication the English find out about the maneuver and divert the escort convoy toward north so that the "Scharnhorst" meets English cruisers instead of the escort convoy. During the ensuing battle "Scharnhorst's" upper "Seetakt" antenna is destroyed. As a consequence, the advantage of the English because of their 9cm radar is increased so that the attempt of the "Scharnhorst" to still locate the escort convoy is found out by the English radar. During the time it takes for that maneuver, the "Duke of York" arrives at the scene. She locates the Germans, who are oblivious to what's going on, at a distance of 42km. The "Scharnhorst " is confronted and after a battle of three hours it capsizes on 26 December 1943.

L44.0 Air War 1944

L44.1.1 "Oboe Mark IIF." English Navigation Procedure λ =9cm

The attempts of the English to come up with a navigation procedure using the "Oboe" principle (L43.3.1) in the 10cm range only succeed when they get a tunable magnetron with a pulse power of 40kW from the Americans who also support them in installing it in ground and on-board radars. This is how the navigation procedure "Oboe Mark IIF" is created in October 1943 that is quite resistant to jamming.

<u>January 1944</u>

By January 1944 the radar is ready for operation.

L44.1.2 "Oboe Mark III." English Navigation Procedure λ =9cm

"Oboe Mark III" is a further development of type "Mark IIF." The ground pulse that is transmit the unit from the Sollkurs has a width of 4µs that decreases with increasing deviation to 1µs. Because each airplane gets a different sequential pulse frequency, it can be used by several airplanes at the same time.

<u>5 June 1944</u>

The procedure is used at the invasion of France in June 1944.

L44.1.3 AN/APN-9. American "Oboe" On-board Receiver λ =8-9cm

In order to be able to also use the English “Oboe” procedure, the Americans develop the on-board receiver AN/APN-9 for their own airplanes.

L44.1.4 “Anti-Boomerang B”. German Boomerang Jamming Transmitter λ=9.1-9.7cm

Even though the ”Oboe II” procedure with the “Naxos” receiver (L43.7.2) is observed and jammed with a make-shift installation, the Air Force Ministry of the Reich (RLM) does not believe the reports so that General Martini does not know about the existence of “Oboe IIF” until the middle of June 1944.

The jamming installation “Anti-Boomerang B,” built by the Lorenz Company uses the Blaupunkt receiver (L43.7.5) “Korfu 812” a well as the 5kW jamming transmitter “Feuermolch” rebuilt for this particular purpose that like the receiver has a 40x40cm horn antenna.

October 1944

Of the 30 installations seven are ready for operation in October 1944.

L44.1.5 “Kurmark-Stand.” German Boomerang Jamming Installation λ=1.20m and 9cm

Twenty units of the “Kurmark-Stand,” a combination of an anti-boomerang transmitter A (L43.3.5) and an anti-boomerang transmitter B (L44.1.4), are built.

L44.2 “Rotterdam” Camouflage Attempts λ=9cm

In the panorama images of the “Rotterdam” radar, rivers and lakes are especially conspicuous. To camouflage them, poles with reflecting frame crosses attached are put on floats in the rivers and lakes. Even though they accomplish the camouflage, they are too sensitive mechanically and work only on one wave length. Triple mirrors work better, but they are detected as single targets by the 3cm panorama radar with higher resolution.

The project “Triberg” at the test laboratory for high frequency research in Ulm undertakes tests to come up with active camouflage. For this purpose a transmitter positioned as high as possible with a pulse power of 100kW is modulated to the frequency of the approaching “Rotterdam” radar

and synchronized with its pulse frequency so that its pulses reflected from the ground render the "Rotterdam" image illegible.

End of 1944

At the end of 1944, two prototype units are built by Telefunken. Since the complexity is too great, no more devices are built.

L44.3 "Berlin" Radars. German Panorama Radars l =9cm

8 February 1944

In February 1944 Leo Brandt, an engineer at the Air Force Ministry of the Reich (RLM), evaluates the activity of the "Rotterdam" research team within the last year and highlights the advantages of the cm wave lengths which are not yet generally acknowledged. He proposes a detailed program to develop the cm technology that leads, among others, to the development of the 9cm radars of the "Berlin" series. Some of these devices are ready for operation, for others only prototypes are ready by the end of the war.

L44.4.1 "Meddo." American Aircraft Panorama Radar l =3cm

While the Germans work feverishly to develop a jamming device for 9cm radars, the Allies are already deploying 3cm radars. In December 1943 an American airplane with a 3cm panorama radar is captured is" Meddo."

L44.2 H2X ("Rotterdam X"). English Aircraft Panorama Radar l =3cm

February 1944

In February 1944 the English equivalent of the American "Meddo" is captured.

L44.4.3 "Naxburg." German Direction-Finding Receiver l =9 and 3cm

It is not difficult to observe the 3cm radars since the "Naxburg" direction-finding receivers that were originally built for the 9cm range are also able to clearly receive the 3cm wave from the antenna's third harmonic.

L44.5.0 The Allies Land in the Normandy

6 June 1944

The landing of the Allies during the night of 5/6 June 1944 (Overlord, X-Day) is accompanied by jamming and deception maneuvers that had been long prepared.

L44.5.1 Mandrel

After a big part of the German radars had been destroyed by bombs, three groups of airplanes equipped with 2.40m jamming transmitters are deployed over the English Channel in order to destroy the remaining "Freya" installations.

L44.5.2 "Taxable" and "Glimmer"

With the help of windows continuously being dropped from low altitudes a deception of ship convoys approaching the French coast at 7 knots is created. The planned and continuously changing targets are determined with the help of the GEE procedure (L42.3). To continue the deception even when reconnaissance planes are used, a small fleet of boats is deployed that carry reflectors fastened to balloons and "Moonshine" jamming transmitters (L42.6.1).

L44.5.3 Titanik

Using dropped dolls, windows, and other means, two groups of airplanes feign the landing of parachute troops at two different places.

L44.5.4 "Tinsel"

English ground stations and an additional group of airplanes equipped with the English jamming transmitter "ABC-VHF" (Airborne Cigar) jam the radar frequencies in the area where

German night fighter planes are expected. The deception is successful and causes the German counter measures to be too late.

L44.6 GH ("Discus"). English Navigation Procedure l =1.50m

The GH procedure is a reversal of the "Oboe" procedure. A pair of ground transmitters sends the pulses received from airplanes back. The time difference in recorded cycles measured on board shows the course with an accuracy of ±100m. In contrast to the simple "Oboe" procedure, it can be used simultaneously by several airplanes as well as for the approach of different targets. The GH procedure is used to attack military targets, especially V1 and V2 launch pads.

L44.7.0 "Stördorf Feldberg"

<u>August 1944</u>

In order to better coordinate the jamming transmitters, they are combined into groups called "jamming villages" ("Stördörfer"). In August 1944 a big installation is built on the Feldberg in the Taunus Mountains to jam the GEE and GH procedures (L42.3.1) and (L44.6). It consists of the following jamming transmitters:

L44.7.1 "Heinrich 1 and 2." German Jamming Transmitter l =5.80-7.10m

Jamming transmitter with a power of 0.5/1.5kW (L42.3.3).

L44.7.2 "Feuerhilfe." German Jamming Transmitter l =3.30-5.00m

To jam the GEE procedure, the **Ln-Ver.Rgt.** "Köthen" develops the jamming transmitter "Feuerhilfe" with an output power of 30kW. Thirty units are built.

L44.7.3 "S600 Feuerzange 1 and 2." German Jamming Transmitter l =5.80-7.10m

Siemens builds the "Feuerzange" transmitters with an output power of 1000kW to jam the GEE procedure. Their pulses are simultaneously sent with several sequential frequencies.

L44.7.4 “S601 Feuerstein 1 to 4.” German Jamming Transmitter λ=1.50-15.00m

The output power of the “Feuerstein” series, built by Telefunken , is a good 100kW. The pulses are sent with mixed sequential frequencies. The types S601/1 and S601/2 send pulses that are synchronized with the GEE procedure in order to jam them. The transmitters are also used for the “Truhe” procedure, the equivalent of the GEE procedure for which the airplanes are equipped with the receiver FuG122 and 123, respectively. Occasionally, the English GE chain are used together with them.

November 1944

The “Stördorf Feldberg” is completed by November 1944. Bombers attack it on 2 March 1945 and destroy 90 percent of it.

L44.8 FuG 350Z Naxos Z. German On-Board Visual Direction Finder λ=9-12cm

The “Naxos” receiver (L43.7.2) gets an antenna rotating at 1,200rpm consisting of two dielectric strip arrays with a diode connected via a high-pass filter. The reading is on a CRT whose synchronously rotating beam is lit up by the receiving pulse. With this the night fighter planes could locate “Rotterdam” aircraft at a distance of up to 100km (50km).

In September 100 “Naxos Z” radars are delivered to the navy.

L44.9 “Rotterheim.” German Gun Laying Panorama Radar λ=9cm

The improved panorama radar “Berlin” (L43.8) is installed on the 3m mirror of the “Mannheim” installation (L42.4) an deployed as gun laying radar called “Rotterheim.” Because of its sharply focused beam of about 0.1 degrees it is resistant to windows.

End of 1944

A small number is produced during the last months of 1944.

S44.0 Sea War 1944

S44.1 “Schnorchel.” German Procedure to Protect Submarines

To enable submarines to charge their batteries without surfacing, they are equipped with a tube called “Schorchel” to provide air for the diesel engines. Even though the “Schnorchel” makes it more difficult to locate submarines, especially at rough seas, it cannot prevent the submarine from being detected because the constantly shorter wave lengths of the radars make is possible to bcate smaller targets.

S44.2 “Sumpf, Schornsteinfeger.” German Submarine Camouflage

Several procedures are tried to prevent detection by radar of those parts of the submarine that are above the water surface.

In most cases measures that are supposed to disperse received signals are selective and difficult to put into practice for a greater range of wave lengths.

<u>Fall 1944</u>

Overlays of absorbing materials, e.g., rubber with deposited semiconductor materials are more promising. If the layer is thick enough, they are effective not only at short but also at long waves lengths as shown by a test flight with a 1.50m ASV radar at the German Aeronautic Research Institute (DVL). At this test the submarine could be detected only by jamming with a “Metox” warning receiver.

S44.3 FuMB 23 “Naxos ZM1b.” German Direction-Finding Receiver for Ships l =8-12cm

<u>September 1944</u>

One hundred units of the “Naxos ZM1b,” a version of the visual direction finder “Naxos Z” (L44.8) developed for night fighter planes are delivered to the navy until September 1944.

S44.4 FuMB 28 "Naxos ZM4." German Visual Direction Finder for Ships l =8-12cm

The direction finder "Naxos ZM4" is a further development of the type ZM1b. It has a rotating antenna consisting of two dielectric strip arrays. The beam rotating synchronously with the antenna on the visual direction finder is lit up when it receives a signal.

<u>August 1944</u>

The first 22 units of an order of 1,700 direction finders are delivered in August 1944.

S44.5 "FuMB 26 Tunis." German Visual Direction Finder for Ships l =2-4cm and 8-23 cm

The direction-finding receiver "Mücke" (FuMB 25) built by Telefunken consists of a horn antenna with built-in detector. It is only deployed in connection with the direction finder "Cuba I" (S43.7) called "Tunis." The bearing accuracy in the 9cm range is ±10 degrees, in the 3cm range ±3 degrees. When installed in submarines the range is between 25km and 50km.

SS44.6 Deception Devices

The Germans and their enemies use devices that feign ships. They consist of reflectors, in most cases dipoles, carried by balloons or fastened to floating bodies, e.g., the German "Aphrodite" and "Thetis" or the American ship simulator "CXCJ."

S44.7.0 "Berlin" Radars of the German Navy l =9cm

Several devices of the type "Berlin" are developed for the navy in 1944.

S44.7.1 "Renner." German Coast Radar l =9cm

The coast radar "Renner" consists of a "Berlin' radar installed in a 3m or 7.5m mirror. If positioned properly, it locates the masts of a destroyer at a distance of 70km.

S44.7.2 "Berlin." German Panorama Radar for Ships l =9cm

Using the 9cm wave makes it possible to build radars with relatively small dimensions. The ship radar "Berlin," developed with these parameters can be used on all kinds of ships.

S44.7.3 "Berlin U1." German Panorama Radar for Submarines l =9cm

The "Berlin U1" radar has a rotating dish antenna of 65cm diameter mounted on the tower.

S44.7.4 "Berlin U2." German Radar Periscope l =9cm

The antenna of the "Berlin U2" radar is mounted on the periscope and can be raised 16m high so that the commandant can survey the area even when the boat is submerged.

Preliminary tests show that an escort convoy can be discovered at a distance of 20km.

S44.7.5 "Barbara." German Picture Radar l =9cm

Using a 7.50m dish, the "Barbara" procedure focuses the radar beam so sharply that targets can be scanned line by line, identified and charted. At a test in Felsterhaken at the beginning of 1945 the lowering of a boat from a ship is observed.

S44.8 Type 275. English Gun Laying Radar for Heavy Flak l =10cm

The gun laying radar Type 275 is mounted on the flak cannon. Even though it has a limited azimuth resolution, it automatically tracks a target once it is located and transmits the distance and azimuth angle measurements to the gun laying computer.

S44.9 Type 252. English Gun Laying Radar for Light Flak l =3cm

The gun laying radar Type 252, built according to the same principle as the Type 275 (S44.8), is used for the light flak. Both types are ready for operation in 1944, but are only rarely deployed.

S44.10 Remote Control of English Airplanes

The English use robot planes carrying 300kg of explosives that are abandoned by the crew after take off. A fighter plane accompanies the bomber and controls it remotely with a VHF receiver. At the outlet of the receiver there are 12 mechanical resonance relays that respond to the respective sounds. The combination of two sounds each trigger the respective guiding signal. A

robot plane is aimed toward the submarine bunker on Helgoland, however it misses its target.[2] pg 78

<u>End of 1944</u>

A second robot plane is captured on Friesland and its control installation can be examined.

L45 Air War 1945

L45.1 “Roland I.” German Jamming Transmitter λ =8.8-9.8cm

Since the output power of the jamming transmitter “Roderich” (L43.7.5) is completely insufficient, Siemens develops the jamming transmitter “Roland I” in 1944. It has an output power of 30kW with a modulation frequency=100kHz and a pulse power of 300W with a sequential frequency =2-10kHz. Using a 30 degree horn antenna, “Roland I” can completely jam “Rotterdam” radars up to a distance of 30km.

<u>February 1945</u>

In February 1945 the transmitter is deployed to protect the Leuna factories.

Attack on Dresden

<u>15 February 1945</u>

On 15 February 1945 Dresden overcrowded with refugees is bombed and completely destroyed. Two hundred fifty thousand civilians died.

L45.2 “Feuerball.” German Jamming Transmitter λ =8.6-9.4cm

With the “Postklystron” the jamming transmitter “Feuerball” gets a power of around 80W with noise modulation and attains a jamming range of 30km with a 70-degree funnel antenna.

Using a 6 degree horn antenna, which is steared in elevation and azimuth, and help from a “Korfu” directional receiver the range is increased to 40 km.

<u>March 1945</u>

In March 1945 several “Feuerball-transmitters: are deployed at the Leuna factories.

L45.3 “Jagdschloß” (and “Forsthaus”). German Ground Panorama Radar λ =9cm

The panorama radar installation “Jadgschloß” with its great range and a pulse power of 300kW is used for air reconnaissance. Thanks to its sharply focusing antenna of 26x3m rotating at 4rpm it is resistant to enemy jamming attempts to a high degree.

L45.4 “Egerland.” German Radar Installation for the Flak l =9cm

The “Egerland” installation, built by Telefunken, consists of the panorama radar “Kulmbach” that produces an image of an area with a radius of 50km using a big rotating cylindrical antenna as well as the gun laying radar “Marbach” with a 4.50m dish that semiautomatically homes in on the chosen target. An installation is deployed at the flak battery Teltow.

L45.5 “Berlin A.” German Aircraft Panorama Radar l =9cm

The on-board aircraft radar “Berlin A” is the German equivalent to the English “Rotterdam” radar. But it is much smaller and easier to operate. Since the radar is no longer needed because of the war situation only a few prototype units are built.

L45.6 Berlin N1 and N2. German Night Fighter Radar l =9cm

The night fighter Squadron 1 is equipped with the “Berlin N2” radar in 1945.

L45.7 “Pauke S.” German Gun Radar for Night Fighters λ=9cm

The night fighter radar “Pauke S” should enable accurate shooting in zero visibility. At the end of the war the device is still in development.

L45.8 English Airborne Radar for Machine Guns

An English bomber whose side machine guns are equipped with a small gun aiming radar. The display is on a CRT whose needle-shaped rotating beam is lit when it receives an echo signal. A located target first appears as an arc that tightens up to form a circle when the gun is aligned with the target. The radius of the circle decreases with decreasing distance.

Germany’s Surrender

<u>9 May 1945</u>

On 9 May 1945 Admiral Raeder signs the unconditional surrender of Germany.

America Starts the Atom War

<u>5 August 1945</u>

On 5 August 1945 the Americans destroy Hiroshima and three days later Nagasaki by dropping one atom bomb each.

Japan's Surrender

2 September 1945

Japan's surrender is signed on the battle ship "Missouri."

Epilogue

When Hitler signed the fleet accord with England that limited the strength of the German war fleet to 30 percent of the English fleet, he thought that he had proved to England that Germany had no intention to attack England and that its fear of a threat to the empire was therefore unfounded. This was a fatal error: England stayed with its policy of "balance of power" and wanted to prevent an increase in Germany's power at any cost so that the desperate attempt of Heß to prevent the war with England was doomed from the very beginning.

England guaranteed protection for Poland while Poland brutally pursued a systematic Polish nationalization of the German areas promised to them after World War I. Now Poland thought it could pursue the destruction of anything German without any constraints. This gave Hitler the probably welcomed reason to start his campaign against Poland. That, in turn, caused England to declare war on Germany on 3 September 1939 and to force the hesitating France to follow suit.

Churchill, who boasts in his memoirs to have prepared two wars, had reached his goal. Later, however, he has to admit that "he had slaughtered the wrong pig," and today we see that he initiated the sell-out of the empire, perhaps to the advantage of a united Europe.

When the German troops conquered Poland, the English did not lift a finger, and when the Germans intruded into France, they left the continent in a hurry. Now England itself was in serious danger. In their need the English engaged the Americans, which proved to be rather easy since Hitler's animosity against Jews had alienated influential circles in America.

As a consequence, the United States supported England so massively that war with them became unavoidable.

Now Hitler's dream of a fast victory was definitely over, and his decision to halt all research that could not lead to practical applications within one year proved to be a grave mistake.

The English, on the other hand, prepared themselves for a prolonged war. They advanced their technical development and even engaged the United States, that had not yet been involved in the war, in this effort. Thus they gained a lead of several years.

After changing their approach by the end of the war, Germany was able to catch up with the English lead in technology. But that was too late for any military benefit.

Germans acted according to the principle that the best is just good enough. The Englishman, Watson Watt, however, called for the third best device: "You never get the best device, and the second best comes too late."

The English, for example, built a chain of radars to protect their coast even though they only had the 12m wave length available, an impossible situation from today's point of view. They also deployed ASV devices for sea reconnaissance even though, according to their own reports, the failure rate was 50 percent.

In contrast, the Germans delayed the deployment of an urgently needed night fighter aircraft radar by a whole year because the Air Force Ministry of the Reich (RLM) insisted that the antennas be mounted inside the airplane, something that in the end turned out to be impossible.

Another principle concerns secrecy. In England the military and the scientists worked together from the very beginning and no important military secrets were leaked to the Germans as proved by the project "Chain Home." In their predicament the English even entrusted all their secret plans to the Americans.

On the other hand, German radar secrets were being leaked to the US. For example all of the Telefunken radar patents were also patent applied for and granted during the war in the US. As such, the German military did everything is could to keep the radar secrets from leaking out. People who worked on a project got to know only the one particular aspect they were directly involved in. There was no central point that had all the information. The Navy and the Air Force pursued their separate developments and established their own observation installations without exchanging data on their results.

To make things worse, the military, with few exceptions, underestimated the importance of technology and thought they could make technical decisions without consulting the experts. So it happened that out of short-sighted presumption, officials in charge did not pass on important information about enemy procedures heeding the motto "What shouldn't be must not be" and

delayed the reconnaissance of the “Oboe” procedure for many months, to mention but one example.

Editors note:

Despite Germanys large technical lead at the beginning of the war, the English and the US caught up with Germanys radar technology in about 1942 by employing hug amounts of resources. The MIT Radiation Laboratory alone spent over $2 billion over the five years during the war.[6] *Only the development of the atom bomb during WWII could rival by cost an approximate equal amount.*

The kill ratio in combat of German Air Force fighters in combat against Allied aircraft was on the average of 7 to 1 although the Allied aircraft outnumbered the German aircraft by as much as 10 to 1 and in some cases up to 100 to 1. It is obvious that the war was not lost because of strategic mistakes or lack of technology or valor. It was not a question of if the Allies would win the war, most Germans during the war knew the answer, but “how long would the war last and what would happen to Europe after the war?”

References

1. Cajus Bekker, **“Augen durch nacht und Nebel.”**
2. Fritz Trenkle, **“Die deutschen Funkstoerverfahren bis 1945.”**
3. **“50th Anniversary IEE-Seminar”** Tagungzbericht.
4. Paul Schmalenbach, **“Schwerer Kreuzer Prinz Eugen.”**
5. Gehrard Hepcke, **Personal experiences with coworkers of the Deutsche Versuchsanstalt fuer Lufttahrt, DVL.**
6. Louis Brown, **“A Radar History of World War II”** Institute of Physics Publishing Bristol and Philadelphia. 1999.